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SOME FACTORS RELATED TO THE PHYSIOLOGY OF EARLINESS OF FOUR VEGETABLE CROPS

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled

"Some Factors Related to the Physiology of Earliness of Four Vegetable Crops"

submitted by Edward Brendan Casement, in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

Earlier maturing cultivars of vegetable crops are necessary for extending the harvesting period and for the growing of a greater range of crops in areas of short growing seasons.

To date studies have mainly been concerned with the physiology of seed germination, of flowering and of harvest, with little research being done on the physiology of vegetative earliness.

In this study the percentage of the five elements, nitrogen, potassium, phosphorus, calcium and magnesium in the leaves of plants at four and three weeks after germination was investigated in order to relate nutrient content to vegetative earliness in the three vegetable crops - cabbage, lettuce and radish. Only one significant correlation was obtained, that being on radish and % Calcium. However in most cases significant differences were obtained among the nutrient levels of the different cultivars.

The limited data obtained in the labelled phosphorus experiment could not be statistically analysed but the technique could be utilized in future work, particularly on uptake studies.

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INTRODUCTION

The short growing season on the Canadian Prairies is an important limiting factor in the production of vegetable crops. The development of earlier cultivars of vegetables can not only bring more crops into successful production, but can also extend the period when fresh locally grown vegetables are available on the market.

Earlier maturity can be manipulated by cultural techniques such as the production of early transplants in the greenhouse and the use of "Hot-caps". However, the most important method of obtaining earlier cultivars could be by breeding. The large population of plants that a breeder must grow for selection is very time consuming and costly. If a simple test could be developed to indicate the earliness of a selection at an early stage of development, a considerable saving could be realized.

Pandita (21) endeavored to find a relationship between the % phosphorus, % dry matter, chlorophyl content and malic acid content of leaf tissue and earliness. Badani (3) conducted experiments concerning the relationship of % phosphorus, % calcium, shoot:root ratios and the net assimilation rate to earliness, while Molnar (17) evaluated pH, total sugars, and the relative amounts of malate and citrate as a criteria for earliness in tomatoes. These researchers have developed some tests which, by themselves or with other tests not yet developed, may provide future breeders with a

means of determining earliness.

The investigations described in this thesis were undertaken to determine if any of the five elements, nitrogen, phosphorus, potassium, calcium or magnesium, were related to earliness in cabbage, lettuce and radish. An attempt was also made utilizing Cerenkov radiation to determine the uptake of P^{32} from Hoagland's solution by tomatoes and cabbage.

I REVIEW OF LITERATURE

INTRODUCTION

That a difference in mineral composition of cultivars of a species occurs has been recognized for about forty years (6, 26). However, there have been few attempts to relate these differences to early maturity. Some workers have tried to relate these differences in mineral composition to factors within the plant and in turn relate these to yield.

A. VARIATIONS IN MINERAL CONTENT

Early work on corn (*Zea mays* L) by de Turk *et al* (6) showed that some selections of several inbred strains, although similar in external characteristics, were somewhat less similar in their behavior. The most notable difference being their response to phosphate fertilizer. The cross that gave increased yield with phosphate fertilizer was also earlier maturing. Smith (26), also working on corn, noted that, in a group of cultivars, the cultivars which did best on poor soils were different to the cultivars which did best on rich soils. He suggested that relative maturity did not account for these differences. He then studied the effect of nitrogen and phosphorus on twenty-four inbred lines and twenty-three single crosses of corn to determine the relative amounts of growth with different levels of nitrogen and

phosphorus. Various media were used and growth was measured at six weeks. Many of the lines behaved alike, however, some showed distinct differences when the phosphorus supply was limiting. Differences in the growth of the corn on the various levels of nitrogen were small. The differences due to the varying levels of phosphorus and nitrogen appeared earlier in the sand and water culture treatments but occurred in all the media used in the investigation. Marked differences in the ratio of secondary to primary roots were found, with the higher ratios of secondary to primary roots being found on the lines which did best on the lower phosphate levels. These differences were found to be inherited and not due to the media or level of nutrient.

In an experiment with labelled phosphorus, Rabideau et al (23) used two inbred corn plants and their hybrid. The hybrid plant, when compared to its parents, attained its greatest radioactivity earlier, had a larger root system, and reached maturity earlier. They surmised that the rapid early development and maturity was due to differences in the vascular organization.

In a review article on varietal differences in plant nutrition, Vose (28) recognized that there were two factors that could account for differences in mineral content - a differential yield response, concerned with dry matter production, and a differential nutrient uptake rate, shown by the concentration of an element in the plant parts. He

points out that the differential yield responses are due to internal factors of nutrient use such as absorption, translocation, assimilation and detoxication. Smith (25) suggests that the mineral composition is dynamic as it is dependent upon changes that take place during the growth processes. He recognized that some elements are present in high concentrations in young tissue and are diluted as the tissue enlarges. Others are present in iow concentrations in young tissue and gradually increase. The accumulation of dry weight dilutes all elements unless there is a further influx of minerals to offset this effect.

Significant differences in mineral composition were found between clones of Ryegrass hybrids (Lolium perenne x L. multiflorm) by Buttler et al (4) for all elements except potassium, and that except for potassium, these differences were inherited. There were, however, no differences between growth and mineral content, and, being a perennial crop, maturity was not considered.

Most of this work on the differences in concentration of elements in cultivars was performed some years ago and has not received universal acceptance. An example of this is the work of Noggle (18) who investigated the total concentration of potassium, sodium, calcium, magnesium, nitrate, phosphate, sulphate and chloride in sixteen crop species in an effort to assess their nutrient requirements. At no time did he mention the cultivars of the crops involved.

However, Howlett (13) in a growth analysis study on some vegetables, found significant differences in some elements between cultivars. He points out, however, that a standardized leaf sampling procedure was necessary. When Ward (29 and 30) did growth analysis studies on tomatoes and cucumbers, he specified which leaves he had taken for analysis, and also the cultivars involved. MacKay and Leefe (16) determined the optimum levels of nitrogen, phosphorus and potassium in specified leaves of sweet corn (Zea mays cv. Carmelcross) and snap beans (Phaseolus vulgaris cv. Kinghorn Golden Wax). A range of fertilizer treatments and four levels of irrigation were used in an effort to maximize yields. In conclusion they stated "The general applicability of the optimum levels derived cannot be projected beyond the limits investigated with certainty", and that other soil types, other cultivars and other variations in environmental conditions would have an effect upon the optimum levels of nutrients for maximum yields.

B. VARIATIONS IN MINERAL COMPOSITION AS RELATED TO MATURITY

Although as early as 1933 de Turk (6) found that one of the selections of corn with which he worked responded to phosphorus and gave earlier maturity, it is only the work of Pandita (21) and Pandita and Andrew (22) that relates mineral composition to maturity.

Pandita did a study on the phosphorus content of tomato

(Lycopersicon esculentum L.), cabbage (Brassica oleracea var. capitata L.), lettuce (Lactuca sativa var. capitata) and radish (Raphanus sativus L.) and related it to maturity. At six and eight weeks after germination a high negative correlation was obtained between the phosphorus content of the sixth leaf and days to maturity in the tomato. In lettuce there was a significant negative correlation at eight weeks, and in cabbage at thirteen weeks between phosphorus content and days to maturity. A positive correlation between phosphorus content and days to maturity was obtained with radish at fifteen, twenty-five and thirty-five days after germination.

In trials with tomatoes, cabbage and lettuce, Badani (3) did not find any correlation between days to maturity and % of phosphorus in tomatoes, sampled at three, five, seven and nine weeks after germination. In cabbage a significant negative correlation was obtained at nine weeks after germination only in one of the four crops grown. However, in lettuce a significant positive correlation was obtained at three weeks after germination in his first crop, a highly significant negative correlation at seven weeks in the second crop, and in the third crop significant negative correlations were obtained in the samples taken at five and seven weeks after germination. Badani (3) also analysed the tissue obtained in his experiments for calcium and found that only in the first of the three tomato experiments and

at seven weeks after germination was a significant negative correlation obtained. In cabbage he found significant positive correlations between the % calcium and days to maturity in the four crops grown, in the first at three weeks, in the second at seven weeks, in the third at three weeks, and in the fourth at three, seven and nine weeks after germination. In lettuce only the second of the three crops grown showed positive correlations, a highly significant correlation was obtained at five weeks after germination, and a significant correlation at seven weeks after germination.

C. ION UPTAKE BY PLANTS

The nutrient levels in the soil and their mobility are factors which affect the level of nutrients in the plant. Ions become available to the plant through a combination of three ways, according to Corey and Schulte (5). Firstly, by root interception, where the plant roots as they grow through the soil occupy space formerly occupied by absorbable nutrients and in the displacement process come into close contact with these nutrients. Therefore a plant with a small but fibrous root system will deplete the media in its vicinity to a much greater extent than a plant with an extensive root system which has a relatively large amount of soil available. Secondly by mass flow where water is constantly moving to or past the surface of plant roots. Some of this water is absorbed by the plant to replace water lost

by transpiration. As the soil water contained dissolved nutrients so the amount of a nutrient which arrives at the root in the soil water arrives there by mass flow. Thirdly, by diffusion. All nutrients are soluble in various degrees and the rate of diffusion to the root surface is dependent upon the diffusion coefficient of the nutrient, the absorbing surface of the plant root, the fraction of the soil volume occupied by water and the concentration of the soluble nutrient. Although a certain amount of all ions are available to the plant through root interception, all of the nitrogen ions and most of the calcium and magnesium ions are supplied by mass flow while diffusion accounts for most of the phosphorus and potassium.

Epstein and Jeffries (11) point out that there may be differences between strains, cultivars or inbred lines of different crops in various physiological processes related to ion absorption and translocation. They considered it unfortunate that the materials chosen for experimentation have been bred for maximum productivity under agricultural conditions with fertile soils. These plants may therefore be less efficient than wild species in absorbing nutrients which have been developed under limited nutrient supplies. They later pointed out that the genetic effect of ion transport can be due to either the mechanisms of absorption from the media or to the movement of ions within the plant tissue.

When reviewing work on ion absorption, Epstein (10)

showed that there were three factors that made it possible to delineate the pattern that the absorption of a single ionic species from the external medium into the plant is governed by two different mechanisms which are sometimes diametrically opposed in their characteristics and responses to environmental factors. The first factor that made it possible to delineate this theory of a dual pattern of ion absorption was that workers used solutions similar in concentration to all those found naturally. Second, that adequate calcium was found to be essential. Third, a technique had been developed for the precise measurement of the rates of absorption. He then discussed the site of the ion absorption, suggesting that the outer cytoplasmic membrane, or plasmalemma, is the site of the first high affinity mechanism and the tonoplast the site of the second. In the first mechanism ions pass through the plasmalemma by diffusion and it is considered the rate limiting step. The second mechanism is located in the vacuolated cells of the tonoplast, and is considered a rate limiting factor. He concluded by suggesting that the first mechanism is important for the uptake of ions from very dilute solutions, and is highly selective. The second mechanism could explain the uptake of ions from high salt concentrations, such as those found in saline conditions. Under these conditions unlike ions mutually compete, minimizing the possibility that one ionic species will dominate.

Dunlop and Bowling (7, 8, and 9) demonstrated that there was uniform transport of potassium ions across the various cells in excised corn (Zea mays) roots, and gave a description of the driving forces involved in the movement of both potassium and chloride ions. They tentatively suggested that the movement of these ions was inherently related to the structure of the root. The greater surface area on the outer edge of the symplasm will have more "pumps" than the lesser surface area on the inner edge of the symplasm. Thus there will be a net influx of ions, without a metabolic gradient or specialized transport cells, which have not been observed.

This work would have been doubted by Anderson (1) as the techniques used involved penetration of the cells of the excised roots by a microelectrode which distorts the cell membrane giving possible erroneous results.

Anderson supports Epstein's theory of the dual pattern of ion uptake, and also supports the theory that ion uptake by root tissue is connected with the organic acid levels in the cell. The ion uptake by the plant may be regulated by two other mechanisms. The first he described as taking place in an actively growing plant, where most of the ions taken up by the roots are transported to the xylem system. The second takes place in a non-actively growing plant and most of the ions are recirculated, the ions passing from the phloem tissue to the xylem and only a few ions being trans-

ported to the xylem from the cortical symplasm.

The need for proof of these proposed mechanisms is stressed by Epstein, Anderson and Legget (15). The present evidence has been obtained from excised portions of plants. Whereas in growing plants there is indiscriminate mutual competition between unlike ions, which would suggest the second type of uptake. This evidence can be misleading when extrapolated to include the whole plant, and until the whole system is evaluated the rate limiting steps in transport and accumulation will remain unknown.

D. OTHER FACTORS RELATED TO EARLY MATURITY

A different approach to earliness was used by Molnar (17). He tested the levels of citric acid, malic acid, pH and total sugars at seven stages of fruit development in the tomato and related these criteria to earliness.

Although in an earlier experiment a comparatively low pH indicated earliness, later experiments proved otherwise. He tested seven characteristics which should be considered when breeding for earliness, these dealt with the levels of malic and citric acid in the fruit during development and suggested that these characteristics may prove useful when selecting material for a breeding program.

He also pointed out that the selection of breeding material by visual means was not reliable as human factors and seasonal conditions vary considerably.

Pandita (21) approached the problem of selecting seedlings for early maturity by determining the chlorophyll content of cultivars and relating this to maturity. He found a positive correlation at six weeks after germination in tomatoes, but none later. In cabbage there was no correlation at five weeks after germination but there was a correlation at the 5% significance level at seven weeks and a positive correlation at the 1% level of significance at nine weeks. It appeared that the earliest cabbage cultivars developed a greater portion of their chlorophyll content at an earlier age than the later cultivars and contained about the same amount as they aged. However, in the later cultivars the chlorophyll content increased with age. This relationship, he concluded, could possibly be used in breeding programs, once the age at which the most significant levels occurred was determined for each crop.

The relationships between the shoot:root ratio and days to maturity and between net assimilation and days to maturity was also studied by Badani (3). He found that there were some positive significant correlations between the shoot: root ratio and days to maturity in tomatoes, cabbage and lettuce, suggesting that the lower the shoot:root ratio, the earlier the cultivar can be expected to mature. In the study on net assimilation at different temperatures and light intensities he found that the late maturing cultivar had a tendency to be a more efficient photosynthesiser during the

earlier stages of development than at later stages while in the earlier cultivar the opposite took place, and from these results he suggested that different cultivars of a species respond in different ways to changes in age, light and temperature.

II. MATERIALS AND METHODS

A. EXPERIMENTAL DESIGN

Experiment 1. Tomato Greenhouse Trial

This preliminary trial was undertaken in the fall of 1967.

Six cultivars of Lycopersicon esculentum L., ranging in maturity from early to mid season, namely:

Bush Beefsteak

Early Fireball

Early Lethbridge

Manitoba

Rocket

Starfire

were seeded in October, 1967 in fiber packs in a 1:1 fine sand, peat mix and germinated in a warm greenhouse. One week after germination 48 of the most vigorous and uniform seedlings of each cultivar were pricked out into 10 cm plastic pots. The growing media was a 3:1:2 soil mix. Two replicated trials were set up in the greenhouse, there were three plants of each cultivar in each of four replications per trial. One trial received no fertilizer and the other received an application of 50 ml per pot of a solution fo 20-20-20 fertilizer at 50 gm per 8,000 ml of water once a month, equivalent to 80 kg/ha of nitrogen, 35 kg/ha of phosphorous and 66.4 kg/ha of potassium.

Seven weeks after germination the fifth leaf, both

lamina and petiole were removed and bulked with those of the same cultivar and replication.

These tomato plants were grown in a greenhouse maintained at 20°C nights and 24°C days. Observations and records were taken daily when the plants began to flower.

For analysis all the samples of each cultivar were bulked to provide an adequate size of sample.

Experiment 2. Cabbage Field Trial

Seven cultivars of Brassica oleracea var. capitata L., ranging in maturity from early to late, were sown in fiber packs containing a 1:1 mixture of fine sand and peat moss on April 1, 1969. The market packs were placed in a cool greenhouse and covered with glass until germination took place, six days later.

The seven cultivars and sources were:

Copenhagen Market Late	Stokes Seeds Limited
Danish Ballhead	Harris Seed Co.
Early Marvel	Stokes Seeds Limited
First Acre	A. E. McKenzie Co. Ltd.
Glory of Enkhuisen	Keystone Vegetable Seeds
Pennstate Ballhead	Stokes Seeds Limited
Small Acre	A. E. McKenzie Co. Ltd.

One week after germination, sixty of the most uniform seedlings of each cultivar were pricked out into veneer bands containing a 3:1:2 mixture of soil, peat and coarse sand.

The bands were placed in flats, and each flat contained two cultivars chosen at random and set up to provide four replications. Four weeks after germination ten seedlings from each cultivar in each replication were harvested, the largest true leaf from each plant, including both the lamina and the petiole, was removed and prepared for analysis, while the remainder of the plant was discarded.

Seven weeks after germination (May 26th) the remaining plants were field set at Parkland Farm, the Horticultural Field Laboratory of the Department of Plant Science of the University of Alberta. They were planted in a randomized block with five plants of each cultivar in each of the four replications. At the time of planting each plant received approximately 550 ml of a starter solution consisting of 50 gm of 10:52:17 fertilizer per 8,000 ml of water. This plot had been summerfallowed for the previous two years. Soil samples analysed by the Alberta Soil and Feed Testing Laboratory showed satisfactory levels of nutrients, therefore additional fertilizer was not applied. During the course of the trial weeding was done by hand.

Observations were taken weekly until the plants started to mature, after which records of maturity were taken twice weekly until all the plants were mature.

Experiment 3. Cabbage Greenhouse Trial

Seven cultivars of Brassica oleracea var. capitata L., ranging in maturity from early to late, were obtained from

Stokes Seeds Ltd.:

Badger Ballhead

Bonanza

Early Marvel

Eastern Ballhead

Emerald Acre

Pennstate Ballhead

Round-up-Hybrid.

Two of the cultivars (Early Marvel and Pennstate Ballhead) from Experiment I were retained and five were replaced by others in order to observe the relationships in a wider range of cultivars. These were sown in fiber packs on November 7, 1970, in a 1:1 fine sand, peat mix and germinated in a cool greenhouse. Germination took place on November 12th, and the seedlings were pricked out one week later. In this case 100 of the most vigorous and uniform seedlings were selected and pricked out to 20 cm plastic pans. The growing media was a 3:1:2 soil mix and there were five plants per pan. Three weeks after germination the four outer plants from each pan were harvested. The two oldest true leaves were removed and bulked with those of the same cultivar and replication, and prepared for later analysis.

The cabbage were grown in a greenhouse with supplemental lighting. During the winter they received a minimum of 850 foot candles for fourteen hours per day. The temperature in the greenhouse was maintained at 10^{o}C nights and

15°C days. On March 25th, the whole experiment was moved to another greenhouse to take advantage of the better natural lighting. During the period of growth under the lights each pot was given a monthly application of 100 ml of a solution of 50 gm of 20:20:20 fertilizer per 8,000 ml of water, which is equivalent to 40 kg/ha of nitrogen, 17.5 kg/ha of phosphorus and 33.2 kg/ha of potassium. This was increased to weekly applications after being moved into the second greenhouse. Observations were taken daily with maturity records being taken twice weekly.

Experiment 4. Lettuce Greenhouse Trial

Five cultivars of Latuca sativa var. capitata L., selected for their range in maturity were obtained from Stokes Seeds Limited, namely:

Jack Frost

Minetto

Minilake

Pennlake

Premier Great Lakes.

These five cultivars were seeded on November 7, 1970 in fiber packs using the same procedure used in the cabbage greenhouse experiment. However, seven plants were pricked out into the 20 cm pans and six of these plants were harvested after three weeks from germination. The plant in the center being allowed to develop to maturity. 100 ml of a solution containing 50 mg of 20:20:20 fertilizer per 8,000 ml of water

was applied to each pot monthly and the lettuce remained under artificial lights in the greenhouse until mature. The lights were adjusted to give 850 foot candles at plant height made up of a combination of 50% fluorescent and 50% incandescent lamp wattage ratio.

Experiment 5. Radish Growth Chamber Trial

On March 6, 1971 five cultivars of Raphanus sativus L., chosen from the catalog for their range in maturity and obtained from Robertson's Seed and Feed Ltd., were sown directly into 15 cm pans. The five cultivars were:

Cavalier

Comet

Red Boy

Red Prince Improved

White Icicle.

The pans contained a 3:1:2 soil mix as used in the other three experiments. Ten seeds were placed in five locations in the pan. There were five pans per replication and four replications. These pans were placed in a Coldstream Growth Cabinet in a randomized block. The cabinet was maintained at 12.5°C for nights and 17.5°C for fourteen hour days, with a 50% relative humidity. The plants were exposed to 1,400 foot candles made up of a 6:1 fluorescent:incandescent lamp wattage ratio.

Two days after germination the seedlings were thinned to one per location in the pans. Three weeks after germin-

ation four plants from each pan were harvested, the two oldest true leaves of each plant were removed and bulked with others of the same cultivar and replication. The remainder of the plants were discarded. The plant in the center of the pan was allowed to mature, with observations being taken daily.

Experiment 6. Uptake of P^{32} by Tomatoes and Cabbage

Four cultivars of Lycopersicum esculentum L. Early Fireball from Stokes Seeds Limited, Manitoba from Stokes Seeds Limited, Rutgers from Peto Seeds, Pearson Select from Peto Seeds, listed in order of maturity were seeded on April 3, 1971 in market packs containing a media consisting of one part of fine sand and one part of peat moss. The basis of the cultivar selection was the range in maturity.

Four cultivars of Brassica oleracea capitata L.:

Emerald Acre

Copenhagen Market Late

Eastern Ballhead

Badger Ballhead

listed in order of maturity and again chosen for their range of maturity and obtained from Stokes Seeds Limited were seeded in a similar manner on April 4, 1971.

Germination took place on April 10th for both the tomatoes and cabbage. On April 17th the three most vigorous and uniform seedlings of each cultivar were pricked out in 15 cm glass dishes, previously treated with a silicon solution, containing perlite. The roots of each seedling were washed

to remove the sand/peat media. The seedlings were arranged in the dish in two circles. The center circle contained one plant of each of the four cultivars while the outer circle contained two plants of each cultivar, in randomized order. One dish contained the tomato seedlings and the second, the cabbage. The dishes were watered daily with Hoagland's solution (Hoagland and Arnon, 12) until April 30th when distilled water was applied.

On May 1st, 10 mc of P^{32} in H_3PO_4, obtained from the Internation Chemical and Nuclear Corp., California, were diluted to 200 ml with Hoagland's solution. At 9:00 a.m., 90 ml of this solution were applied to the dish containing the tomatoes. At 9:30 a.m., 90 ml were applied to the dish containing the cabbage. Twenty-four hours later the plants were harvested and cut up into six parts, namely:

1. That section of the stem between the top of the media and the cotyledons.
2. The cotyledons.
3. The two internodes between the cotyledons and the second leaf.
4. The whole of the first leaf.
5. The whole of the second leaf.
6. The growing tip above the second leaf.

These samples were placed in previously weighed glass liquid scintillating vials and weighed.

B. ANALYSIS OF THE MINERAL CONTENT

1. Sample Preparation

The fresh leaf samples, of all but the P^{32} experiment, including both the lamina and the petiole, were dried in an oven at 60°C for twenty-four hours, then ground to a fine powder using a mortar and pestle. The samples were then mixed well and stored in glass vials until required for analysis.

2. Analysis

a. Nitrogen

Total ammoniacal and organic nitrogen was determined by a microkjeldahl method (2). Duplicate 0.05 g samples of the dried ground plant material were placed in 30 ml microkjeldahl flasks. To each was added 1.9 g of potassium sulphate, 0.4 ml of a solution of magnesium sulphate (o.16 g of MgO made up to 100 ml with concentrated H_2SO_4), three boiling chips and 3.0 ml of concentrated sulphuric acid. The samples were digested until clear and colorless. After cooling slightly 5.0 ml of distilled water was added to prevent precipitation. A thin film of vaseline was placed on the tip of the flask and the digest was transferred to the distillation apparatus. A 125 ml erlyenmeyer flask containing 5 ml of 4% boric acid was placed under the condenser. 8 ml of a solution consisting of 50 g NaOH and 5 g $Na_2S_2O_3 \cdot 5H_2O$ diluted to 100 ml with distilled

water was added to the digest and the solution was heated with a small flame until about 15 ml of distillate was collected. This distillate was titrated against 0.02 N hydrochloric acid using Methyl red-methylene blue indicator. Blank determinations were run with every batch.

b. The Other Ions

A stock solution was prepared from the dried plant samples using a wet digestion method (19).

Duplicate samples of 0.05 g dried plant material were transferred to 20 ml pyrex test tubes, to each was added 4 ml of a mixture of concentrated sulphuric acid, 70% perchloric acid and concentrated nitric acid (ratio 1:1:8), mixed, and placed in a 600 ml beaker containing 300 ml of fine dry sand, so that $\frac{1}{4}$ of the tube was in the sand. The beaker was then placed on a hot plate and covered with a glass fume hood connected to a water aspirator. The hot plate was switched on, and the thermostat set to maintain the beaker at 180^{o}C. The digestion was continued until the acid mixture was volatilized and the remaining solution was clear. The test tubes were removed from the beaker, the residue taken up with 5 ml concentrated hydrochloric acid and 5 ml of 6N hydrochloric acid. This solution was transferred to a graduated centrifuge tube using the 6N hydrochloric acid and made up to 25

ml with the same acid. The contents were stirred and centrifuged at 12,000 rpm for 10 minutes. The supernatent liquid was decanted into clean bottles and stoppered firmly.

Phosphorus

Phosphorus was determined in the first experiment by the official method of A.O.A.C. (2).

A 1.0 gm sample of dried, ground plant material was placed in a porcelain crucible, 1.0 ml of Magnesium nitrate solution (950 gm of $Mg(NO_3)_2 6H_2O$ in 1,000 ml of distilled water) was added and the sample was placed on a steam bath. After a few minutes a few drops of concentrated Hydrochloric acid were added cautiously to prevent frothing, further additions of concentrated hydrochloric acid were added so that the sample tended to char as it approached dryness. The crucibles, when dry, were covered and transferred to a cold muffle furnace and ignited for six hours at 500°C. When cool the ash was taken up with 20% hydrochloric acid and transferred to 100 ml beakers. Five ml of hydrochloric acid were added and the samples evaporated to dryness on a steam bath. The residue was moistened with 2 ml of hydrochloric acid, about 50 ml of distilled water was added and reheated for a few minutes and then the solution was transferred to 100 ml volumetric flask, cooled, made up to volume and filtered. The first

portion of the filtrate was discarded.

Five ml aliquots of the filtrate were placed in 10 ml volumetric flasks, 1.10 ml of ammonium molybdate solution (25 gm ammonium molybdate was dissolved in 300 ml distilled water to which was added 75 ml of concentrated sulphuric acid diluted to 200 ml) was added and the flask swirled, after a few minutes 1.0 ml of hydroquinone solution was added (0.5 gm of hydroquinone dissolved in 100 ml distilled water to which one drop of concentrated sulphuric acid was added), flask swirled and 1.0 ml of sodium sulphite solution (200 gm sodium sulphite dissolved in distilled water and made up to 1,000 ml) was added. The flask was made up to volume with distilled water, mixed and allowed to stand for 30 minutes.

The developed color was read immediately in a Bausch and Lomb Spectronic 20 colorimeter set at a wavelength of 650 mu. Concentrations of phosphorus were read off a standard curve prepared from reading of known solutions of potassium phosphate treated identically.

Phosphorus on the second to fifth experiments was determined by the Murphy and Riley method (as described by Watanabe and Olsen (31)).

The color developing reagent was prepared by taking 1,000 ml of $5N \cdot H_2SO_4$ adding to it 12 g of ammonium

molybdate in 250 ml of distilled water and 100 ml of distilled water in which 0.2908 g of antimony potassium tartrate had been mixed. After thorough mixing the volume was made up to 2,000 ml with distilled water. To 200 ml of this solution 1.056 g of ascorbic acid was mixed, as required.

Five ml aliquots were taken from the stock solution, diluted to 250 ml with distilled water. Five ml of this solution was placed in a 25 ml volumetric flask, 15 ml of distilled water and 4 ml of the ascorbic acid reagent were added and the solution was brought up to volume with distilled water. The developed color was read on a Bausch and Lomb Spectronic 20 colorimeter set at a wavelength of 882 mu. The phosphorus content of the sample was obtained by comparing the absorbance read against a standard curve prepared from samples containing a known amount of phosphorus prepared from chemically pure KH_2PO_4.

Potassium, Calcium and Magnesium

Five ml aliquots of the stock solution were diluted to 50 ml with distilled water, (for calcium and magnesium 1% lanthanum as lanthanum oxide was added before making up to volume) and aspirated into a Dial Atom Mark II Atomic Absorption Spectrophotometer set at the correct wavelength for each of the three elements being investigated. The amount of each element was

read off a standard curve obtained from dilutions of Standard Reference Solutions supplied by the Fisher Scientific Company Ltd., Chemical Manufacturing Division, Fair Lawn, New Jersey, U.S.A.

C. DETERMINATION OF THE P^{32} UPTAKE

The amount of P^{32} taken up by each portion of the tomato and cabbage plants was determined by utilizing Cerenkov Radiation (24).

Ten ml of the labelled Hoagland's solution was transferred to a glass liquid scintillating vial, and a further 10 ml used to make a series of dilutions so that 10 ml of the dilutions contained 1.0 ml, 0.1 ml, 0.01 ml and 0.001 ml of the labelled Hoagland's solution.

The weighed samples were ashed at 500°C in glazed porcelain crucibles, the ash taken up with 0.5 ml of concentrated hydrochloric acid filtered into the original vial, the filter paper washed washed with distilled water, the solution neutralized with sodium hydroxide and the volume made up to 10 ml with distilled water.

The vials containing the Hoagland's solution and the samples were counted on May 3rd and May 17th in a Nuclear Chicago Mark I Liquid Scintillating System using channels B and C set to give a channel ratio of 3:1 with a standard Tritium sample. The samples had to be counted the second time, after holding for two weeks in a refrigerator to allow a half life of P^{32}

to pass since they had too high a count the first time.

III. RESULTS

1. TOMATO GREENHOUSE TRIAL

Statistical analysis was not attempted on this trial since insufficient plant material was available for the duplicate analysis of individual replications. The unfertilized plants flowered twelve to twenty-eight days later than the fertilized plants but not in the same order. The percentage roots, on a dry matter basis, appeared to have a strong relationship to days to flower in the plants that were under stress. There also appeared to be a relationship between the phosphorus content and the dry matter content of the fifth leaf seven weeks after germination and days to flower on the four Prairie bred tomatoes - Rocket, Early Lethbridge, Starfire and Manitoba. There did not appear to be any relationships between days to flower and the phosphorus percentage or dry matter content of the non-stressed plants.

These results are presented in Table 1.

2. CABBAGE FIELD TRIAL

Statistical analysis showed that there was a significant difference in the nitrogen levels between the cultivars and a highly significant difference between the cultivars in potassium levels. There were no differences in the levels of phosphorus, calcium or magnesium. There were no significant correlations between any of these elements and

Table 1. The relationship between days to maturity and phosphorus % and dry matter % of leaf tissue of non-stressed and stressed plants of six cultivars of Lycopersicon esculentum L., seven weeks after germination. (Greenhouse, Fall 1967).

Cultivar	% P in D.M. @ 7 weeks	% P in Fresh leaves at 7 weeks	% D.M. in leaves at 7 weeks	% Roots @ 10 weeks (D.M. Basis)	Days to Flower
NON-STRESSED					
Rocket	2.38	0.226	9.50	22.5	75
Manitoba	2.55	0.230	9.02	19.0	91
Early Fireball	1.94	0.174	8.96	20.2	92
Early Lethbridge	1.90	0.176	9.24	17.5	92
Starfire	2.21	0.206	9.30	20.5	95
Bush Beefsteak	2.09	0.192	9.18	18.0	100
STRESSED					
Rocket	0.130	0.0167	12.88	26.0	87
Early Lethbridge	0.120	0.0146	12.18	22.9	102
Starfire	0.117	0.0137	11.71	21.5	112
Manitoba	0.104	0.0115	11.03	21.5	117
Bush Beefsteak	0.106	0.0129	12.19	19.0	117
Early Fireball	0.109	0.0122	11.24	17.5	120

Statistical analysis was not performed.

days to maturity at four weeks after germination.

These results are presented in Table 2.

3. CABBAGE GREENHOUSE TRIAL

The statistical analysis indicate highly significant differences at three weeks after germination between the seven cultivars and days to maturity for nitrogen, potassium, calcium and magnesium and a significant difference for phosphorus. No significant correlations were observed between any of the elements investigated and days to maturity.

These results are presented in Table 3.

4. LETTUCE GREENHOUSE TRIAL

Significant differences were observed between days to maturity and the phosphorus and magnesium content of the five cultivars at three weeks after germination, but no differences were found for nitrogen, potassium and calcium. No significant correlations were found between the five elements investigated and the days to maturity of the five cultivars.

These results are presented in Table 4.

5. RADISH: GROWTH CHAMBER TRIAL

A positive correlation coefficient of 0.886, significant at the 5% level of significance was obtained between the % calcium in five cultivars and the days to maturity at three

Table 2. The relationships between days to maturity and Nitrogen, Phosphorus, Potassium, Calcium and Magnesium content of leaf tissue in seven cultivars of Brassica oleracea var. capitata L., four weeks after germination (Field, Summer 1969).

Cultivar	% N	% P	% K	% Ca	% Mg	D.T.M.
Early Marvel	5.02 ab[+]	0.48 ab	4.77 ab	2.6 a	1.02 a	110
First Acre	4.97 ab	0.57 a	5.05 a	2.6 a	1.02 a	112
Small Acre	5.04 ab	0.56 ab	5.00 ab	2.3 a	0.97 a	115
Copenhagen Market Late	5.19 a	0.50 ab	4.35 c	2.6 a	i.12 a	132
Glory of Enkhuisen	4.75 bc	0.50 ab	4.70 b	2.7 a	1.10 a	133
Pennstate Ballhead	4.58 c	0.47 b	4.82 ab	2.7 a	1.12 a	142
Danish Ballhead	4.77 bc	0.52 ab	4.87 ab	2.7 a	1.10 a	149
Correlation	0.131^{NS}	-0.489^{NS}	-0.346^{NS}	0.570^{NS}	0.0083^{NS}	

[+] Numbers which are not followed by the same letter are significantly different from each other at the 5% level of significance as judged by Duncan's New Multiple range test (23).

NS Not significant.

D.T.M. Days from germination to maturity of 60% of the plants of each cultivar.

Table 3. The relationships between days to maturity and Nitrogen, Phosphorus, Potassium, Calcium and Magnesium content of leaf tissue in seven cultivars of Brassica oleracea var. capitata L., three weeks after germination (Greenhouse, Winter 1970-71).

Cultivar	% N	% P	% K	% Ca	% Mg	D.T.M.
Early Marvel	5.93 b[+]	0.53 ab	4.37 b	2.4 bc	0.77 bed	149
Emerald Acre	5.74 c	0.55 a	4.30 b	2.3 d	0.79 abc	177
Badger Ballhead	5.81 bc	0.51 abc	3.85 c	2.5 a	0.81 ab	184
Round-up-hybrid	5.57 d	0.48 bc	4.35 b	2.5 a	0.83 a	188
Pennstate Ballhead	5.53 d	0.57 a	4.50 b	2.5 ab	0.75 cd	188
Bonanza	5.72 c	0.48 bc	3.95 c	2.3 cd	0.75 cd	223
Eastern Ballhead	6.13 a	0.55 a	5.27 a	2.4 cd	0.74 d	231
Correlation	0.471^{NS}	0.166^{NS}	-0.325^{NS}	-0.680^{NS}	-0.197^{NS}	

[+] Numbers which are not followed by the same letter are significantly different from each other at the 5% level of significance as judged by Duncan's New Multiple Range Test (23).

NS Not significant.

D.T.M. Days from germination to the maturity of 60% of the plants of each cultivar.

Table 4. The relationships between days to maturity and Nitrogen, Phosphorus, Potassium, Calcium and Magnesium content of leaf tissue of five cultivars of Latuca sativa var. capitata L., three weeks after germination (Greenhouse, Winter, 1970-71).

Cultivar	% N	% P	% K	% Ca	% Mg	D.T.M.
Minnilake	5.08 a[+]	0.60 bc	7.85 ab	0.78 a	0.56 bc	91
Minetto	5.17 a	0.66 a	7.77 ab	0.66 a	0.55 c	95
Pennlake	5.07 a	0.62 ab	7.33 b	0.70 a	0.59 b	100
Premier Great Lakes	4.96 a	0.56 c	8.15 a	0.71 a	0.55 c	103
Jack Frost	5.30 a	0.63 ab	7.60 ab	0.18 a	0.63 a	110
Correlation	0.0499[NS]	0.0396[NS]	0.0255[NS]	0.565[NS]	0.661[NS]	

[+] Numbers which are not followed by the same letter are significantly different from each other at the 5% level of significance as judged by Duncan''s New Multiple Range Test (23).

NS Not significant.

D.T.M. Days from germination to the maturity of 60% of the plants of each cultivar.

weeks after germination. No significant correlations were observed between the four other elements being investigated and days to maturity. Highly significant differences were obtained between the five cultivars for potassium, calcium and magnesium, and a significant difference between cultivars for nitrogen.

These results are presented in Table 5.

6. UPTAKE OF P^{32} BY TOMATOES AND CABBAGE

a. No significant differences were found between the amounts of phosphorus taken up by the different cultivars of tomatoes at three weeks after germination. A correlation coefficient was not attempted since plants had not been grown to maturity. However, there appeared to be a relationship among the maturities of the cultivars and the phosphorus content of the internodal tissue between the cotyledons and second leaf. A similar relationship was evident in reference to the phosphorus content of the first leaf.

The results of this experiment are presented in Table 6.

b. No significant differences were found between the amount of phosphorus taken up by the cabbage at three weeks after germination. A correlation coefficient was not attempted since plants had not been grown to maturity.

The results of this experiment are presented in Table 7.

Table 5. The relationships between days to maturity and Nitrogen, Phosphorus, Potassium, Calcium and Magnesium content in five cultivars of Raphanus sativus L., three weeks after germination (Growth Chamber, Spring 1971).

Cultivar	% N	% P	% K	% Ca	% Mg	D.T.M.
Cavalier	5.88 a[+]	0.55 a	4.35 bc	1.33 b	0.60 b	24
Red Boy	5.88 a	0.56 a	4.53 ab	1.23 b	0.57 b	24
Red Prince Imp.	5.86 a	0.58 a	4.10 d	1.35 b	0.61 b	25
Comet	5.60 b	0.58 a	4.73 a	1.35 b	0.59 b	25
White Icicle	6.04 a	0.56 a	4.23 cd	1.58 a	0.66 a	27
Correlation	0.490^{NS}	0.327^{NS}	0.367^{NS}	0.886^{*}	0.732^{NS}	

+ Numbers which are not followed by the same letter are significantly different from each other at the 5% level of significance as judged by Duncan's New Multiple Range Test (23).

NS Not significant.

* Significant at the 5% level.

D.T.M. Days from germination to the maturity of 60% of the plants of each cultivar.

Table 6. The relationship between days to maturity and the amount of Phosphorus taken up during twenty-four hours by four cultivars of Lycopersicon esculentum L., three weeks after germination (Spring, 1971).

Cultivars in order of maturity	p.p.m. Phosphorus in fresh plant tissue						
	Stem - media to cotyledons	The cotyledons	Stem - the internodes between the cotyledon and the second leaf	The first leaf - both lamina and petiole	The second leaf - both lamina and petiole	The growing tip	Total
Early Fireball	35	27	103	63	145	236	609
Manitoba	45	35	109	64	89	198	540
Rutgers	55	38	122	85	105	414	819
Pearson Select	53	35	159	94	83	295	709

No significant differences were obtained on the statistical analysis.

Table 7. The relationship between days to maturity and the amount of Phosphorus taken up during twenty-four hours by four cultivars of Brassica oleracea var. capitata L., three weeks after germination (Spring, 1971).

Cultivars in order of maturity	p.p.m. Phoshporus in fresh plant tissue						
	Stem - median to cotyledons	The cotyledons	Stem - the internodes between the cotyledons and the second leaf	The first leaf - both lamina and petiole	The second leaf - both lamina and petiole	The growing tip	Total
Emerald Acre	55	18	30	32	83	150	380
Copenhagen Market Late	51	17	35	39	89	133	364
Eastern Ballhead	29	7	17	20	42	93	208
Badger Ballhead	115	21	56	39	106	156	493

No significant differences were obtained on the statistical analysis.

IV DISCUSSION AND CONCLUSIONS

The significant positive correlation obtained between the percentage calcium and days to maturity of five cultivars of radish at three weeks after germination was the only significant correlation obtained (Table 5). This is in agreement with the work of Badani (3) who also found significant correlations at some age after germination with cabbage, lettuce and tomato. That there were no correlations obtained with the phosphorus percentage and days to maturity is in general agreement with Badani (3) but not with Pandita (21) who found correlations at some stage of growth in four vegetable crops, tomato, cabbage, lettuce and radish, between phosphorus and days to maturity. This may have been due to the different cultivars used in the different experiments, as some different cultivars were used in order to widen the scope of the experment and to reduce the possibility of working with cultivars which by accident had a correlation between the phosphorus content and days to maturity.

The differences obtained between Pandita (21), Badani (3) and this work suggests that analysing for the element concentrations at some early stage of growth in tomatoes, cabbage, lettuce and radish is not a good way of determining whether or not one cultivar or seedling is earlier than another. This is disappointing since there are now relatively efficient ways of analysing an element concentration (3).

Although Pandita (21) obtained significant correlations

between phosphorus content and days to maturity at six weeks after germination, this was not found in Experiment 1. It is also possible at six weeks after germination to observe indications of earliness. Early cultivars of tomatoes six weeks after germination have well developed flower clusters, while in late cultivars they are just beginning to form. Chronological age is a simple measure but is very subject to the influence of a number of environmental factors, i.e. plants of identical chronological age may differ considerably in appearance on development. There are two other definitions of age which could be considered as a basis of sampling. The "morphological" age, where the plant of a specified size of description could be used, or "physiological" age based on analysis of the changes in the metabolism of the plant. Differences in the concentration of the elements in the leaves may be more pronounced. However, the slower growing cultivars have longer in which to absorb and accumulate nutrients. Molnar (17) warns against using visual indications for sampling because of the subjectivity of human factors. Physiological age is difficult to assess without a laboratory determination as this has to be related to the physiological changes which take place within a plant and these may or may not be related to a morphological change.

Molnar (17) also gives five examples of methods of determining earliness, 1) days to the development of the first flower, 2) days to the set of the first fruit cluster, 3) days

to ripening of the first fruit, 4) days to the ripening of the first three fruit and 5) days to the first harvest; all have advantages and disadvantages.

One of the disadvantages of using the opening of flowers as an indication of earliness is the inability of some cultivars of tomatoes to set fruit below a certain temperature, while others, which have been developed on the Canadian Prairies are able to set fruit at a lower temperature. The ripening of three fruit was used as a criteria of maturing by Pandita (21) but this again is subjective and requires complete knowledge of the ripening characteristics of all the cultivars used in an experiment.

In Experiment 1, the days from germination to the opening of the third flower was taken as a criteria for earliness. The order of maturity of the cultivars in this late fall crop did not correspond with those obtained by Pandita (21). It is possible that some cultivars are more able to utilize the low light received during this period and developed flower buds accordingly.

The stressed plants in Experiment 1 (Table 1) appeared to have a relationship between days from germination to the opening of three flowers and the percentage of roots at ten weeks after germination. These plants showed definite signs of phosphorus deficiency and the experiment was not repeated as the nutrient levels in the soil were not monitored and the maturity dates did not correspond to those obtained by Pandita

(21) or to the published reports of the tomato cultivar trials undertaken by the Horticultural Division of the University of Alberta. The later flowering of the tomato plants growing in the phosphorus deficient media emphasizes the importance of phosphorus on plant maturity. Different levels of phosphorus in the media could contribute to the differences found in the % phosphorus in the leaf tissue by Pandita (21), Badani (3) and this work.

According to Smith (24) there are three general periods in the life of a leaf. Firstly, there is a general influx of minerals into a young leaf during expansion and for a short period after when metabolism is high. This is followed by a period of change as senescence approaches and mobile elements are withdrawn and finally a period of minimal change. He cautions the reader to consider the increment of growth when interpreting concentrations in the leaves. This could also have a bearing on the differences in levels of nutrients found between Pandita (21), Badani (3) and this work. The choice of leaf and the general vigour of the plant is of major importance. At three and four weeks after germination even the oldest leaves are still expanding and there is a general influx of nutrients. The rate at which elements accumulate in the leaves is largely dependent upon environmental factors.

The amount of light that a plant receives has a bearing upon the ion uptake in that the more light a plant receives,

up to a saturation point, the more the plant will photosynthesise and the more water and ions are required. As the amount of light is reduced, so is the rate of photosynthesis, until it becomes limiting where photosynthesis and respiration are equal, below this level there can be accumulation of ions through transpiration but there is no build up of products of photosynthesis. Temperature also affects the rate of ion accumulation, as temperature increases from a threshold value all processes within the plant increase until a maximum is reached after which the processes slow down. The plants in these experiments were grown in the field where seasonal variations in both temperature and light occured, or in the greenhouse where only a minimum temperature was maintained. Light quality and quantity decrease during the winter months and seasonal variations have a bearing upon plant production causing differences in nutrient levels in the plant.

A study of Pandita's data (21) indicated that the earlier cultivars reach a maximum phosphorus content earlier than the later cultivars. In Experiments 2 and 3 (Tables 2 and 3) the samples were taken at four weeks after germination then three weeks after germination in an attempt to discover if the earlier cultivars took up the elements faster than the later cultivars. This earlier sampling was made possible on a reasonable scale by the micro-analytical methods developed by Watanabe and Olsen (31) and modified by Omanwar (20)

The five major elements were determined rather than the

single element phosphorus, as Kraus and Kraybill (14) showed that there was a relationship between the nitrogen content and maturity, and with a standard nutrient supply for all cultivars a higher percentage of nitrogen may indicate lateness. The stock solution for phosphorus was readily usable for the determination of potassium, calcium and magnesium by the Atomic Absorption Spectrophotometer.

The lack of correlation between the percentage of the elements at three and four weeks after germination in these experiments with cabbage, lettuce and radish are not in agreement with the suggestion that earlier cultivars take up elements much faster than the later cultivars at that stage. The significant differences obtained in the analysis of variance again prove the necessity of specifying the cultivars used when a tissue analysis program is being undertaken (13, 14, 16, 28, 29).

The strong indication of a relationship between the % phosphorus in the leaves of the stressed plants (Table 1) when only considering the four Prairie bred tomato cultivars (Rocket, Early Lethbridge, Starfire and Manitoba) may be the result of a breeding program using the same parents. These cultivars may be more closely related to the wild species, which according to Epstein and Jeffries (11), are more efficient in absorbing nutrients under limited nutrient supply. However, the work of Butler et al (4) points out that differences in mineral composition are inherited. If this is

the case it is possible for a parent in a cross to have a high phosphorus content and this could be passed on to the offspring. When selecting the earlier cultivars from such a cross a higher phosphorus content might be obtained. However, if the phosphorus content is not linked with earliness it would not be a good basis for the selection of earlier maturing cultivars. Similarly a low nitrogen content or lower potassium, calcium and magnesium percentage would not guarantee earliness, especially at the three and four week stage after germination.

Finding a factor positively related to earliness at an early stage of growth has distinct advantages as testing at later stages requires a major labor input in the production of transplants and setting them out.

It is quite possible that some factors can be correlated to earliness after the plants have been set out in the field, however, the advantages would be lost. Molnar (17) worked on the fruit of tomatoes and suggested that a factor may be found in the fruit that could be utilized in the breeding of tomatoes for earliness. It would be useful if a factor could be found in the fruit that was related to the earliness of the plants grown from the seed from that fruit, as the labor input would be small.

Smith (26) found that the plants that were best able to utilize the available phosphate in the media had a high secondary to primary root ratio. Badani (3) found relationships

between the shoot:root ratios in tomatoes, lettuce and cabbage indicating that the lower the ratio the earlier the cultivar. Rabideau et al (23) using labelled phosphorus found that the hybrid corn plant, which was earlier maturing than its parents, had a higher shoot:root ratio than its two inbred parents and that it was able to take up the labelled phosphorus in larger quantities. According to Smith (26) this is due to the dominance of branched root types in corn hybrids which he also found to be able to take up nutrients faster, and he considered it to be one of the favorable factors causing hybrid vigor.

In the labelled phosphorus experiment (Table 6) there is a trend in the later maturing cultivars to have higher phosphorus levels in the internodes between the cotyledons and the second leaf, and in the first leaf, than the earlier maturing cultivars. Badani (3) found in a net assimilation trial that Burpees Big Boy, the latest maturing cultivar, seemed to be a more efficient synthesiser than the earlier maturing cultivars during the early stages of its development. This would suggest that since the root systems of the later maturing cultivars are supporting relatively more top growth than the earlier cultivars, that they are more efficient in taking up nutrients and water in order to sustain the higher rate of photosynthesis. As development progresses the earlier maturing cultivars maintain a lower shoot:root ratio but the differences in the shoot:root ratios decrease indicating that

the efficiency of the root system in the later cultivars is offset by the relatively larger size in the earlier maturing cultivars. Hybrid cultivars were not used in these investigations or by Badani (3) which could account for the serious differences found.

The very high readings obtained in Experiment 6 (Tables 6 and 7) on cabbage and tomatoes using Cherenkov Radiation and counting in a liquid scintillating system while using only a relatively small amount of labelled phosphorus, could be utilized to measure the small amounts of phosphorus taken up by young plants in only a few minutes. Although phosphorus is converted to relatively insoluble forms in soil, as compared to nitrogen which for the most part remains in soil solution, it can be applied in a soluble form which is immediately available to the plant. It might then be possible to relate the phosphorus absorption to a type of root system which is more efficient and relate this to earliness.

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